A New Keynesian IS Curve for Australia: Is it Forward Looking or Backward Looking?

Antonio, Paradiso and Kumar, Saten and Rao, B Bhaskara

University of Rome La Sapienza, Auckland University of Technology, University of Western Sydney

25 November 2011

A New Keynesian IS Curve for Australia: Is it Forward Looking or Backward Looking?

Antonio Paradiso

anto_paradiso@hotmail.com

Department of Economics, University of Rome La Sapienza, Rome (Italy)

Saten Kumar

kumar_saten@yahoo.com

Department of Economics, Auckland University of Technology, Auckland (New Zealand)

B. Bhaskara Rao

raob123@bigpond.com

School of Economics and Finance, University of Western Sydney, Sydney (Australia)

Abstract

This paper estimates the forward looking, backward looking and an extended version of the New Keynesian *IS* curve for Australia. The validity of these models is investigated by imposing the constraint on real rate of interest and as well as when the constraint is relaxed. Two measures of output gap viz. *GAP1* (constructed using the unobserved components approach) and *GAP2* (constructed using a quadratic trend) are utilized. Our results suggest that the baseline backward looking and forward looking models are overwhelmingly rejected by the data. Evidence strongly supports for the extended backward looking model (with *GAP2*) being relevant for monetary policy analysis.

Keywords: New Keynesian IS curve; Backward looking; Forward looking; Australia

JEL: C2; C12

1. Introduction

Recent research has explored the New Keynesian *IS* (*NK-IS* henceforth) curve but in most applications the findings are inconclusive. Compared to the New Keynesian Phillips curve (*NK-PC* henceforth), empirical investigations into the *NK-IS* curve are limited. Theoretically, both are purely forward looking. While the *NK-PC* explains inflation to expected future inflation and the output gap, the *NK-IS* curve links output gap to expected future output gap and the ex-ante real interest rate. The failure to attain robust estimates in a purely forward looking (*FL* henceforth) model has led many researchers to utilize the hybrid version which incorporates both *FL* and backward looking (*BL* henceforth) elements. Empirically, the *BL* model often produces estimates that are consistent with the data (Rudebusch, 2002; Linde, 2001; Goodhart and Hofmann, 2005). Since monetary policy is generally viewed as having mostly short run real effects on the economy, therefore an investigation into the *NK-PC* and *NK-IS* curve yields useful implications on the relevance of monetary policy. Specifically, the estimates of *NK-IS* curve signify whether the monetary policy will have statistically significant impact on the aggregate demand.

This paper utilizes the specifications in Goodhart and Hofmann (2005) to estimate the *NK-IS* curve for Australia over the period 1984Q1 to 2010Q3. The contribution of this paper is threefold. First, we investigate whether the *BL* model fit the data better than the *FL* model. This is of special interest because in many studies the estimates of real rate of interest are either wrongly signed or statistically insignificant at the conventional levels; Nelson (2001, 2002) has called this finding the *IS* puzzle. No attempt has yet been made to assess the *NK-IS* curve for Australia using country-specific time series data. Second, we explore the validity of the *BL* and *FL* models when the real interest rate assumption is relaxed. To this end, nominal interest and inflation rates, in their own right, could also affect output. We relax this assumption partly due to the perspective of Davidson et al. (1978) that it is worth to explain the complete set of existing findings. They argued that restrictions derived from economic theories can be valuable in econometric modelling if correctly implemented to restrict the model but not the data. Lastly, we address the issue of stability of the *NK-IS* curve. For the *NK-IS* curve to be a good model for policy makers, its structural parameters should not vary in a systematic manner over-time and hence should be stable.

Our results suggest that the baseline *BL* and *FL* models fail to produce statistically significant relationship between the real interest rate and output gap. The unconstraint version (real interest rate relaxed) yields estimates that are fairly consistent with the constraint version (real interest rate included). Extending the *FL* model did not yield any conclusive results, however an extension into the *BL* model with *GAP2* (output gap computed using a quadratic trend) by including additional terms such as growth in real base money, real broad money and real share prices produced statistically significant estimates for real interest rate (nominal interest and inflation rates) in the constraint (unconstraint) equations. Robustness tests revealed that estimates of our extended *IS* curve are robust and to this end we infer that monetary policy has significant real effects in Australia. Furthermore, our results also imply that it is vital to integrate other variables in the baseline dynamic stochastic general equilibrium (DSGE) models; these variables are growth in real base money, real broad money and real share prices for the case of Australia.

This paper is organized as follows. Section 2 provides a review of the studies that have analyzed the *NK-IS* curve and also offers potential explanations for the *IS* puzzle. Section 3 discusses the data and specifications used in this paper. Section 4 details our empirical results, and Section 5 concludes.

2. Empirical NK-IS Curve and the Puzzle

Empirical Evidence on NK-IS Curve

Due to the interest sensitivity of the *IS* curve, and given that it determines interest rates, monetary policy can steer aggregate demand. The *IS* curve defines real aggregate demand as a negative function of the real interest rate. In its simplest form, the *IS* curve is determined by the inter-temporal Euler equation:

$$y_t = E_t y_{t+1} - \sigma\left(i_t - E_t \pi_{t+1}\right) + \eta_t \qquad (1)$$

where y_t is the output gap, $E_t y_{t+1}$ is the current period's expectation of next period's output gap, i_t is the nominal interest rate, $E_t \pi_{t+1}$ is the current period's expectation of next period's inflation rate and η_t is an aggregated demand shock not anticipated by the central bank and hence it is not correlated serially with a statistical mean of zero. Note that the ex-ante real interest is used, defined as $i_t - E_t\pi_{t+1}$, and its negative coefficient reflects inter-temporal substitution effects in consumption. Equation (1) is purely forward looking and in empirical applications the pure *FL* model was found to be inconsistent with the dynamics of aggregate output (see for example Estrella and Fuhrer, 2002). Consequently, equation (1) is substituted with a hybrid version in order to match the lagged and persistent responses of inflation and output to monetary policy measures that are found in the data, for instance see Fuhrer and Rudebusch (2004). Fuhrer (2000) showed that such hybrid specification can be theoretically motivated by habit formation in consumption. Fuhrer (2000) and Fuhrer and Rudebusch (2004) estimated the *FL* model for the USA and found limited evidence that *FL* expectations are important in output determination. Fuhrer and Rudebusch (2004), in particular, asserted that Generalized Method of Moments (GMM) estimates are problematic due to weak instruments, and that maximum likelihood estimation may be preferable.

With regard to the *BL* model, Rudebusch and Svensson (1999) have achieved a statistically significant negative coefficient for the real rate of interest. Peersman and Smets (1999) and Angeloni and Ehrmann (2007) attained similar results for the Euro Area and therefore their findings supports the *BL* model. Other studies asserted that additional measures such as monetary aggregates, asset prices, real effective exchange rate etc. should be included in the *BL* specification, for example see Nelson (2001, 2002), Hafer et al. (2007), Hafer and Jones (2008) and Goodhart and Hofmann (2005). Nelson (2001 and 2002) estimated the *BL* model for UK and the USA and fails to find a significant negative coefficient for the real interest rate. In the case of the USA, Hafer et al. (2007) found that movements in real M2 significantly affect changes in the output gap independent of the real federal funds rate. Goodhart and Hofmann (2005) have extended the *BL* model to include asset prices and monetary aggregates for G7 countries.[1] They found statistically significant negative impact of real interest rate on aggregate demand for all countries. Recently, Hafer and Jones (2008) found that for six countries (Canada, France, Germany, Japan, UK and the USA) money, independently of the real rate of interest, exerts a significant impact on the GDP gap. By examining the relative role of the real short-term interest rate and real money in predicting future GDP, they found that real money is the more significant policy measure.

[1] These countries are Canada, France, Germany, Italy, Japan, UK and the USA.

The IS Puzzle

The empirical failure of the *NK-IS* curve has created a puzzle so called the *IS* puzzle (Nelson, 2001 and 2002). Nelson (2001) provided three explanations for this puzzle: 1) simultaneity bias arising from *FL* aspect of monetary policy; 2) mis-specification caused by omission of *FL* elements; and 3) mis-specification due to omission of other variables in the *IS* equation. The first point implies that any attempt to estimate a structural *IS* curve could be questioned and that the analysis of monetary transmission should focus on the effect of the exogenous or unsystematic component of monetary policy. Partly due to this criticism, a number of studies have used the vector auto regression (VAR) approach to estimate the effect of monetary policy.[2] However, as suggested by Goodhart and Hofmann (2005), the VAR approach provides evidence only for the effect of monetary policy shock which accounts for a negligible share of overall interest rate movements, while nothing is learnt about the effects of systematic monetary policy measures. The latter two explanations imply that the *IS* puzzle can be solved by choosing an alternative specification of the *IS* curve. Nelson (2001) argued that omitting *FL* elements in the empirical *IS* curve may also produce a downward biased interest rate elasticity. The third point is of our main interest i.e. other variables besides the short-term real interest rate may influence the aggregate demand.[3]

In extending the *IS* curve, Goodhart and Hofmann (2005) have utilized the following variables: government spending to GDP ratio, real effective exchange rate, changes in real share price index, changes in real base money, changes in real broad money and the US output gap. The government spending is an important component of the aggregate demand and hence it could play an important role in explaining the output gap. Nelson (2002) reports evidence that real base monetary growth has a significant positive effect on the output gap for UK and the USA. In open economy extensions of the *NK-IS* curve (for example see Ball, 1998 and Svensson, 2000) the exchange rate appears to be an additional determinant. Further, share prices and broad monetary aggregates may also influence the aggregate demand via wealth effects, for example a change in wealth, caused by a change in asset prices or broad

[2] For more details, see Watson (1994) and Stock and Watson (2001).
[3] If other variables besides real interest rate affect the aggregate demand, then the estimated interest rate elasticity in the standard *IS* curve specification will be biased. For an explanation of this point see di Giovanni et al. (2009).

money, induces consumers to change their consumption plans. The US output gap has implications on domestic exports and hence could also influence the aggregate demand.

In our view it is vital to consider the economic significance of the included variables in the *IS* curve. The considered variables in Goodhart and Hofmann (2005), Nelson (2002), Ball (1998) and Svensson (2000) contribute to the fit and performance of the *IS* equation. To this end, extending the baseline *NK-IS* curve may solve the *IS* puzzle and perhaps the model could be reliably used by policy makers.

3. Data and Specifications

Data

Our sample includes quarterly data for the period 1984Q1 to 2010Q3. Two measures of output gap are constructed, namely *GAP1* and *GAP2*. *GAP1* is constructed using the unobserved components approach of Harvey (1989 and 2011). Harvey's output gap decomposition is based upon the hypothesis that trend and cycle have a separate dynamic structure and therefore the shocks are uncorrelated in this model (see Harvey, 2011, p.8). The value added of this approach is that it can deal with structural breaks. *GAP2* is constructed using a quadratic trend for potential output in which output is assumed to have a quadratic function in time (see Ross and Ubide, 2001). This could capture the non-linear components of the time series.

Table 1. Descriptive Statistics 1984Q1-2010Q3

Variable	Mean	Std. Dev.	Min	Max
GAP1	0.001	0.012	-0.026	0.035
GAP2	-0.010	0.029	-0.069	0.040
i	8.085	4.331	3.000	18.257
π	3.677	3.549	-7.473	14.015
Oil_{price}	-0.006	0.195	-0.568	0.527
g	0.350	0.078	0.211	0.540
rex	93.015	10.587	76.487	119.740
y^{US}	3.062	0.119	2.877	3.345
Δm	6.408	5.453	-14.325	21.873
Δm^b	-0.881	6.347	-17.536	17.517
Δsp	5.448	17.488	-45.267	67.454

Notes: Std. Dev. = standard deviation, Min = minimum value and Max = maximum value.

Other data include inflation rate (π = annualized rate of change of GDP deflator), quarterly average of monthly cash rate (i), oil price (Oil_{price}), total government expenditure to GDP ratio (g), real effective exchange rate (rex), US output gap (y^{US}), growth in real base money (Δm), growth in real broad money (Δm^b) and growth in real share prices (Δsp). All the data are seasonally adjusted whenever appropriate. Table A1 in Appendix provides details on the definitions and sources of the data while Table 1 presents the key descriptive statistics for all variables.

Specification

We follow Goodhart and Hofmann (2005) (see also Fuhrer and Rudebusch, 2004) and specify a hybrid version of the *FL IS* curve as:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \gamma E_t y_{t+1} + \overbrace{\underbrace{\beta(i_t - E_t \pi_{t+1})}_{\beta_1 i_t + \beta_2 E_t \pi_{t+1}}}^{\equiv R_t} + \varphi\, x_t + \varepsilon_t \qquad (2)$$

where $y_t =$ output gap (*GAP1* or *GAP2*), $i_t =$ nominal interest rate, $E_t \pi_{t+1} =$ expected inflation in the next period, and $x_t =$ a vector of other variables that can influence aggregate demand.[4] The typical x variables we include are Oil_{price}, g, rex, Δsp, Δm, Δm^b and y^{US}. Further, equation (2) includes forward looking output expectations to avoid downward biased interest rate elasticity (see Nelson, 2001). Following Rudebusch and Svensson (1999), Rudebusch (2002) and Goodhart and Hofmann (2005), our specification for the *BL* model is as follows:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \overbrace{\underbrace{\beta(i_{t-1} - \pi_{t-1})}_{\beta_1 i_{t-1} + \beta_2 \pi_{t-1}}}^{\equiv R_{t-1}} + \varphi\, x_{t-1} + \varepsilon_t \qquad (3)$$

[4] Goodhart and Hofmann (2005) provide a good explanation of additional variables that could be used in *IS* curve estimations.

To avoid multicollinearity problem in equations (2) and (3), we first estimate the fully specified model and then progressively eliminate the least insignificant variables until all the retained variables are statistically significant at the conventional levels. However, the main variable of interest i.e. ($i_t - E_t\pi_{t+1}$ in equation 2 and $i_{t-1} - \pi_{t-1}$ in equation 3) is always retained.

Equations (2) and (3) impose the restriction that it is real interest rate (R_t) which is crucial in the *IS* curve. Theoretically, this is pragmatic. An increase in the nominal interest rate is expected to discourage investment and consumption spending, while an increase in inflation expectations (nominal interest rates held fixed) lead to an increase in aggregate demand because of a decrease in the real interest rate. The coefficient of nominal interest rate is expected to be less than zero $(\beta_1 < 0)$ and the inflation coefficient to be greater than zero $(\beta_2 > 0)$. To this end, it is assumed that $|\beta_1| \approx |\beta_2|$. However, other effects of inflation are also possible. For example, Davidson et al. (1978) found a negative impact of inflation on consumption expenditures. Perhaps this could be interpreted as the effect of price changes on the real balances and in such cases β_2 will be negative. Since there exists alternative explanations on the impact of inflation on output, we tend to estimate the *IS* curve with and without the constraint on the real rate of interest.

4. Empirical Results

Backward Looking IS Curve

We start with the estimates of the *BL* version of the *IS* curve. The *BL* model is usually estimated in practice although it is not consistent with the *NK-IS* curve of most DSGE models (see Hafer and Jones, 2008 and Stracca, 2010). The ordinary least squares (OLS) results for the *BL* model are presented in Table 2. Columns (1) and (2) present estimates for the constraint version i.e. real interest rate (*R*) is derived by subtracting lagged one period's inflation rate (π_{t-1}) from the nominal interest rate lagged one period (i_{t-1}). It is assumed that the coefficients of i_{t-1} and π_{t-1} are equal but opposite in sign. In columns (3) and (4), we relax this assumption to examine if nominal interest and inflation rates affects output gap in their own right. The two measures of output gap viz. *GAP1* and *GAP2* are used in both cases. Due to the multicollinearity problem, y_{t-2} is excluded from all equations.

While all the estimated coefficients have expected signs, neither the estimates of real interest rate (constraint equations 1 and 2) nor the estimates of nominal interest and inflation rates (unconstraint equations 3 and 4) are statistically significant at the 5% level. The lagged one period inflation rate is statistically significant at only 10% level in column (4). Further, the lagged one period output gap is statistically significant at the 1% level in all cases, except in column (4). The diagnostic test results show no issues of serial correlation, normality and heteroscedasticity. Overall, these results imply that monetary policy does not have a significant link to the real economic activity.

Table 2. Estimates for Backward Looking Model 1984Q1-2010Q3

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \overbrace{\underbrace{\beta(i_{t-1} - \pi_{t-1})}_{\beta_1 i_{t-1} + \beta_2 \pi_{t-1}}}^{\equiv R_{t-1}} + \varepsilon_t$$

	(1) *GAP1*	*(2)* *GAP2*	*(3)* *GAP1*	*(4)* *GAP2*
α_0	0.098 [1.118]	0.190 [2.071]**	-0.018 [0.129]	0.238 [0.728]
α_1	0.848 [17.311]***	0.942 [9.761]***	0.828 [15.824]***	0.943 [1.142]
α_2	-	-	-	-
β	-0.017 [1.166]	-0.045 [1.115]	-	-
β_1	-	-	-0.009 [0.549]	-0.048 [1.259]
β_2	-	-	0.031 [1.606]	0.038 [1.786]*
$\bar{R}^2$	0.737	0.749	0.745	0.719
LM(1)	0.620	0.369	0.524	0.232
LM(4)	0.773	0.400	0.425	0.695
JB	0.116	0.370	0.542	0.437
BPG	0.182	0.246	0.112	0.205

Notes: The absolute *t*-statistics are reported in [ ]. *LM(1)* and *LM(4)* are Lagrange Multiplier tests for first and fourth order serial correlations of the residuals, respectively. *JB* is the Jarque-Bera normality test of residuals. *BPG* is the Breusch-Pagan-Godfrey heteroskedasticity test. P-values are reported for *LM(1), LM(4), JB* and *BPG* tests. Significance at 1%, 5% and 10% levels are reported by ***, ** and *, respectively. OLS is used to estimate all equations.

Forward Looking IS Curve

The *BL* model we estimated in the preceding sub-section may not be structural and therefore we estimate a hybrid *FL* model as given in equation (2). The GMM estimates for equation (2) are displayed in Table 3. Hansen's (1982) *J*-test indicates that our selected instruments ($y_{t-1}, y_{t-2}, R_{t-1}, R_{t-2}, oil_{price\ t-1}, oil_{price\ t-2}$ and intercept) are valid. Columns (1) and (2) present estimates for the constraint version (real interest rate (*R*) equals nominal interest rate in the current period (i_t) minus current period's expectation of next period's inflation rate ($E_t y_{t+1}$)). The unconstraint equations are given in columns (3) and (4) in which we relax the assumption that nominal interest and expected inflation rates are equal and opposite in sign. Both *GAP1* and *GAP2* are used in the constraint and unconstraint equations but the second lag of respective output gap (y_{t-2}) was statistically insignificant in all cases.

The results show that all the estimates have expected signs and the estimates of the lagged (α_1) and lead (γ) output gaps are statistically significant at the 5% level. However, the constraint coefficient of the real rate of interest (β) is significant at only 10% level in column (2) when this equation is estimated with *GAP2*. The coefficients of nominal interest rate (β_1) and expected inflation rate (β_2) in the unconstraint versions are statistically insignificant at the conventional levels. Moreover, we also utilized the full information maximum likelihood (FIML) to estimate the *FL* model; these results are not reported for brevity. The results reveal that real interest rate (nominal interest and expected inflation rates) in the constraint (unconstraint) equations with respect to *GAP1* and *GAP2* are statistically insignificant at the conventional levels. In all the above equations, the estimates of additional x variables (Oil_{price}, g, rex, y^{US}, Δm, Δm^b and Δsp) were statistically insignificant and therefore were excluded to attain the parsimonious models. Taken literally, the results match with the *BL* model and imply that monetary policy is ineffective in steering aggregate demand.

Table 3. Estimates for Forward Looking Model 1984Q1-2010Q3

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \gamma E_t y_{t+1} + \underbrace{\overbrace{\beta(i_t - E_t \pi_{t+1})}^{\equiv R_t}}_{\beta_1 i_t + \beta_2 E_t \pi_{t+1}} + \varphi x_t + \varepsilon_t$$

	(1) *GAP1*	*(2)* *GAP2*	*(3)* *GAP1*	*(4)* *GAP2*
α_0	0.091 [1.454]	0.193 [1.623]	-0.050 [0.228]	0.128 [0.727]
α_1	0.600 [8.332]***	0.600 [6.421]***	0.575 [5.522]***	0.600 [5.735]***
α_2	-	-	-	-
γ	0.480 [5.530]***	0.369 [3.267]***	0.361 [2.270]**	0.363 [2.732]**
β	-0.019 [1.523]	-0.048 [1.711]*	-	-
β_1	-	-	-0.023 [1.171]	-0.048 [1.464]
β_2	-	-	0.070 [1.076]	0.077 [1.050]
φ	-	-	-	-
$\bar{R}^2$	0.834	0.873	0.842	0.872
JB	0.920	0.874	0.889	0.854
J-test	0.529	0.829	0.833	0.564

Notes: The Newey-West adjusted *t*-statistics for serial correlation and heteroskedasticity are reported in [ ]. Instruments are $y_{t-1}, y_{t-2}, R_{t-1}, R_{t-2}, oil_{price\ t-1}, oil_{price\ t-2}$, plus intercept. *J*-test is the Hansen test for instrument validity and rejection implies the instruments are valid. *JB* is the Jarque-Bera normality test of residuals. P-values are reported for *J* and *JB* tests. $oil_{price\ t}$ is the cyclical component of log oil price obtained by unobserved components approach. Significance at 1%, 5% and 10% levels are reported by ***, ** and *, respectively.

Extended IS Curve

The results attained in the preceding two sub-sections imply that there exists the *IS* puzzle for Australia. Extending the *FL* model did not yield any plausible results, therefore we provide an extension into the *BL* model by including additional terms such as described in the data section, in particular, oil price, total government expenditure to GDP ratio, real effective exchange rate, US output gap, growth in real base money, growth in real broad money and growth in real share prices. Table 4 present OLS estimates for the extended *IS* curve.

The constraint (unconstraint) estimates are given in columns (1) and (2) (3 and 4), respectively. The additional variables that have statistically significant impacts on output gap

Table 4. Estimates for Extended Backward Looking Model 1984Q1-2010Q3

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \underbrace{\overbrace{\beta(i_{t-1} - \pi_{t-1})}^{\equiv R_{t-1}}}_{\beta_1 i_{t-1} + \beta_2 \pi_{t-1}} + \varphi_{\Delta m}\Delta m_{t-1} + \varphi_{\Delta m^b}\Delta m^b_{t-1} + \varphi_{\Delta sp}\Delta sp_{t-1} + \varepsilon_t$$

	(1) *GAP1*	*(2)* *GAP2*	*(3)* *GAP1*	*(4)* *GAP2*
α_0	-0.252 [1.874]*	-0.158 [1.141]	-0.360 [2.062]**	-0.046 [0.283]
α_1	0.837 [13.620]***	0.934 [11.413]***	0.815 [12.734]***	0.912 [11.937]***
α_2	-	-	-	-
β	-0.019 [1.497]	-0.047 [2.809]**	-	-
β_1	-	-	-0.012 [0.839]	-0.054 [3.038]***
β_2	-	-	0.032 [1.553]	0.033 [1.768]*
$\varphi_{\Delta m}$	0.055 [2.816]**	0.054 [2.641]**	0.057 [2.812]**	0.055 [2.722]**
$\varphi_{\Delta m^b}$	0.044 [2.090]**	0.045 [1.924]*	0.042 [2.039]**	0.051 [2.184]**
$\varphi_{\Delta sp}$	0.007 [2.114]**	0.009 [2.510]**	0.006 [1.702]*	0.010 [2.701]**
$\bar{R}^2$	0.763	0.955	0.763	0.955
LM(1)	0.610	0.819	0.526	0.870
LM(4)	0.521	0.480	0.468	0.511
JB	0.938	0.612	0.644	0.830
BPG	0.080	0.345	0.161	0.267

Notes: The absolute *t*-statistics are reported in [ ]. *LM(1)* and *LM(4)* are Lagrange Multiplier tests for first and fourth order serial correlations of the residuals, respectively. *JB* is the Jarque- Bera normality test of residuals. *BPG* is the Breusch-Pagan-Godfrey heteroskedasticity test. P-values are reported for *LM(1), LM(4), JB* and *BPG* tests. Significance at 1%, 5% and 10% levels are reported by ***, ** and *, respectively.

are one period lagged growth in base money, broad money and real share prices.[5] These variables have a positive impact on the output gap and this result is not unexpected. In columns (1) to (4), all coefficients have the expected signs and the lagged one period output gap estimates (α_1) are statistically significant at the 1% level. The constraint coefficient of the real rate of interest (β) is statistically insignificant in column (1) with *GAP1* but is significant at the 5% level in column (2) when this equation is estimated with *GAP2*. The coefficients of the nominal rate of interest (β_1) and inflation rate (β_2) have expected signs, however they are statistically significant at the conventional levels only in column (4).

[5] We did attempt to use these variables in natural logarithms but all were statistically insignificant at the conventional levels.

Further, their magnitudes in absolute value (in column 4) are close as theoretically expected and the application of Wald test (p-value = 0.27) confirmed this restriction. Thus, estimates of the extended *IS* curve with *GAP2* in both its constraint and unconstraint versions have produced consistent results and therefore these are our preferred estimates. The diagnostic tests are also reasonable; see last row of Table 4. The plots of actual and fitted values for columns (2) and (4) are more than satisfactory, see Figure 1 and 2 below. These results imply that the *IS* puzzle unambiguously vanished in the extended *IS* curve especially when the output gap measure is *GAP2* and hence monetary policy seems to be a relevant guide for aggregate demand.

Figure 1. Actual and Fitted Values for Constraint Equation with *GAP2*

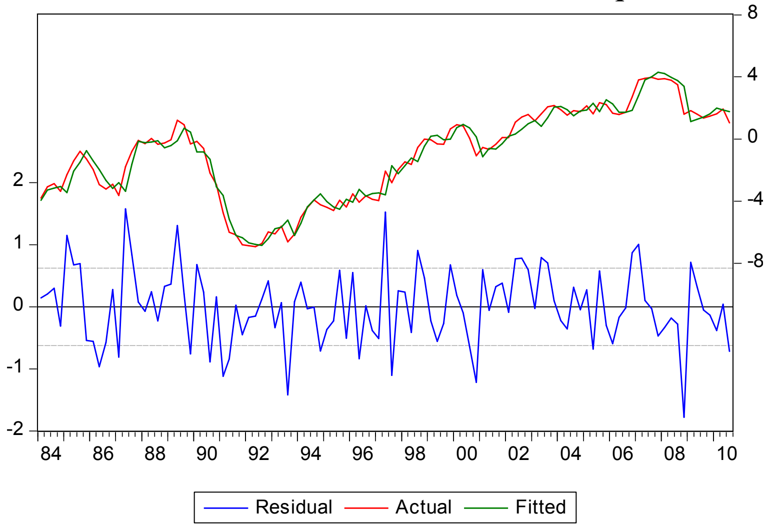
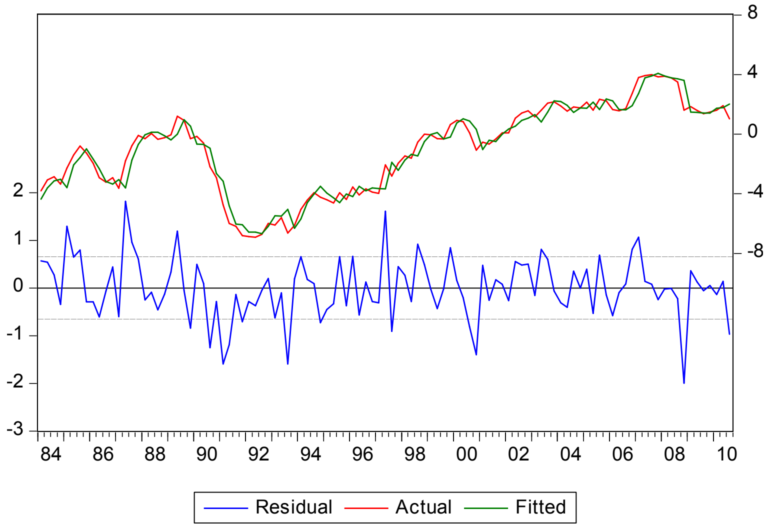


Figure 2. Actual and Fitted Values for Unconstraint Equation with *GAP2*



Robustness

Since the extended *IS* curve yields most significant estimates in the constraint and unconstraint versions with *GAP2*, it is therefore important to assess how robust are these results. In the first instance, we subject our preferred extended *IS* equations (columns 2 and 4) from Table 4 to stability tests. To this end, we applied the Quandt (1960) and Andrews (1993) structural break tests. The Quandt-Andrews test is a modified version of Chow test that allows for dominant endogenous breakpoints in the sample for an estimated equation. The maximum (max F), average (ave F) and exponential (exp F) test statistics are used in this test. The null hypothesis of no break is rejected if these test statistics are large, however Hansen (1997) derives an algorithm to compute approximate asymptotic p-values of these tests. Table 5 reports the Quandt-Andrews breakpoint results.

Table 5. Quandt-Andrews Structural Break Tests 1984Q1-2010Q3

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \underbrace{\overbrace{\beta(i_{t-1} - \pi_{t-1})}^{\equiv R_{t-1}}}_{\beta_1 i_{t-1} + \beta_2 \pi_{t-1}} + \varphi_{\Delta m} \Delta m_{t-1} + \varphi_{\Delta m^b} \Delta m^b_{t-1} + \varphi_{\Delta sp} \Delta sp_{t-1} + \varepsilon_t$$

	Constraint Model with *GAP2*			Unconstraint Model with *GAP2*		
Test Statistics	Break Date	Value	Prob.	Break Date	Value	Prob.
Max LR F-statistic	1990Q2	14.217	0.026**	1990Q2	18.029	0.000***
Max Wald F-statistic	1996Q1	69.010	0.000***	1993Q3	8.298	0.374
Exp LR F-statistic	-	1.388	0.961	-	1.172	1.000
Exp Wald F-statistic	-	28.045	0.000***	-	145.941	0.000***
Ave LR F-statistic	-	2.552	0.925	-	2.246	0.999
Ave Wald F-statistic	-	39.569	0.000***	-	2.367	0.845

Notes: *** and ** means significance at 1% and 5% levels, respectively. The (un)constraint model with *GAP2* are basically estimates from columns (2) and (4) from Table 4, respectively.

The results reveal that there exists a structural break during the 1990Q2, 1993Q3 and 1996Q1. For the constraint model with *GAP2*, all test statistics reject the null of no break at the 5% level except the exp and ave LR F-statistics. The maximum statistics indicate breaks at 1990Q2 and 1996Q1. In the case of unconstraint model with *GAP2*, only the max LR and exp Wald F-statistics reject the null of no break and suggests a break at 1990Q2. Further, a break at 1993Q3 is depicted by the max Wald F-statistics but it is statistically insignificant at the conventional levels. The detected break dates are realistic in regard to the economic incidences which Australia experienced in the last decade. During the 1990-91 period Australia experienced a severe recession that caused shrinkage in the private investment,

Table 6. Robustness

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \overbrace{\underbrace{\beta(i_{t-1} - \pi_{t-1})}_{\beta_1 i_{t-1} + \beta_2 \pi_{t-1}}}^{\equiv R_{t-1}} + \varphi_{\Delta m} \Delta m_{t-1} + \varphi_{\Delta m^b} \Delta m^b_{t-1} + \varphi_{\Delta sp} \Delta sp_{t-1} + \varepsilon_t$$

	Constraint Model with *GAP2*					Unconstraint Model with *GAP2*				
	Recession		Inflation Targeting Regime		GFC	Recession		Inflation Targeting Regime		GFC
	1984Q1-1990Q1	1992Q1-2010Q3	1984Q1-1995Q4	1996Q1-2010Q3	1984Q1-2006Q4	1984Q1-1990Q1	1992Q1-2010Q3	1984Q1-1995Q4	1996Q1-2010Q3	1984Q1-2006Q4
α_0	0.359	-0.140	-0.321	0.086	0.146	-0.685	0.579	-0.897	0.638	-0.039
	(0.587)	(0.970)	(0.632)	(0.422)	(0.594)	(0.493)	(1.387)	(0.990)	(1.437)	(0.214)
α_1	0.772	0.948	0.940	0.932	0.883	0.705	0.939	0.889	0.907	0.929
	(8.032)***	(26.488)***	(13.427)***	(20.505)***	(14.508)***	(5.629)***	(23.044)***	(9.165)***	(18.615)***	(26.313)***
α_2	-	-	-	-	-	-	-	-	-	-
β	-0.024	-0.049	-0.050	-0.031	-0.086	-	-	-	-	-
	(1.730)*	(2.194)***	(1.953)**	(1.644)*	(1.899)*					
β_1	-	-	-	-	-	-0.033	-0.017	-0.034	-0.025	-0.076
						(2.449)**	(1.729)*	(1.726)*	(1.723)*	(3.782)***
β_2	-	-	-	-	-	0.046	0.016	0.079	0.013	0.074
						(1.784)*	(1.890)*	(2.001)**	(1.481)	(2.776)***
$\varphi_{\Delta m}$	0.024	0.047	0.088	0.007	0.057	0.019	0.017	0.093	0.020	0.065
	(1.462)	(2.131)**	(2.046)**	(1.871)*	(2.032)**	(1.826)*	(1.550)	(2.129)**	(1.719)*	(2.624)***
$\varphi_{\Delta m^b}$	0.136	0.044	0.077	0.002	0.063	0.146	0.026	0.075	0.020	0.067
	(1.731)*	(1.641)*	(1.693)*	(1.456)	(1.811)*	(1.824)*	(1.748)*	(1.590)	(1.678)*	(2.299)**
$\varphi_{\Delta sp}$	0.002	0.010	0.009	0.008	0.011	0.002	0.009	0.007	0.007	0.006
	(1.790)*	(2.070)**	(1.677)*	(1.764)*	(1.989)**	(2.237)**	(1.682)*	(1.707)*	(2.282)**	(1.698)*
$\bar{R}^2$	0.726	0.844	0.801	0.750	0.814	0.805	0.744	0.811	0.742	0.877
LM(1)	0.125	0.684	0.224	0.174	0.142	0.224	0.265	0.850	0.200	0.238
LM(4)	0.443	0.993	0.148	0.583	0.327	0.355	0.423	0.741	0.634	0.640
JB	0.101	0.847	0.071	0.401	0.500	0.123	0.126	0.230	0.541	0.225
BPG	0.129	0.760	0.642	0.655	0.541	0.065	0.238	0.554	0.115	0.124

Notes: Chow breakpoint test rejects the null of no break at 1996Q1 for unconstraint model with *GAP2*. GFC stands for global financial crisis. All equations are estimated using non-linear least squares. *LM(1)* and *LM(4)* are Lagrange Multiplier tests for first and fourth order serial correlations of the residuals, respectively. *JB* is the Jarque- Bera normality test of residuals. *BPG* is the Breusch-Pagan-Godfrey heteroskedasticity test. P-values are reported for *LM(1), LM(4), JB* and *BPG* tests. Significance at 1%, 5% and 10% levels are denoted by ***, ** and *, respectively.

employment and output growth rate. The year 1996 signifies the introduction of inflation targeting regime in the performance of monetary policy. The inflation targeting was preliminarily adopted by the Reserve Bank of Australia in 1993, however it was not formally endorsed until 1996.

To assess robustness of the estimates in our extended *IS* curve, we estimated five variants of the (un)constraint models with *GAP2*, respectively, namely (i) sample prior to recession 1984Q1-1990Q1, (ii) sample after recession 1992Q1-2010Q3, (iii) sample prior to the inflation targeting regime 1984Q1-1995Q4, sample after the inflation targeting regime 1996Q1-2010Q3 and excluding the global financial crisis of 2007-2010, by ending the sample period in 2006Q4.[6] These equations are estimated with the OLS and the results are reported in Table 6. Overall, the results are found to be pretty robust in the different variants considered. In particular, it is notable that the coefficients of real interest rate in constraint model have expected sign and are statistically significant at the conventional levels. Similarly, the nominal interest and inflation rates have also the expected signs and are significant at the conventional levels except the sample 1996Q1-2010Q3 in which inflation is insignificant. Further, the additional variables (growth in real base money, real broad money and real share prices) have the expected signs and mostly significant at the conventional levels. These results are consistent with our original extended *IS* curve estimates (see columns 2 and 4 in Table 4). On the basis of these results, we argue that the *IS* curve is predominantly *BL* in an extended fashion both before and after the recession (1990-91). The inflation targeting regime introduced during the 1996 and the global financial crisis of 2007-2010 matters little for the degree of extended *BL* model.

5. Conclusions

This paper has evaluated the *BL* and *FL* specifications of the *NK-IS* curve for Australia over the period 1984Q1 to 2010Q3. In doing so, we have utilized two measures of output gap viz. *GAP1* and *GAP2*. *GAP1* is constructed using the unobserved components approach of Harvey (1989 and 2011), while *GAP2* is computed using a quadratic trend (Ross and Ubide,

[6] Since our sample starts from 1984, it would be improbable to account for some major changes in the monetary policy that took place in the mid to late 1980s, for example, financial liberalization, the Australian dollar float, and formation of the Australian Stock Exchange Limited. Moreover, the 1997-98 Asian financial crisis had very minimal impacts on the output growth for Australia, so it is also excluded.

2001). The validity of the *BL* and *FL* models is investigated by imposing the constraint on real rate of interest and as well as when the constraint is relaxed. The typical *NK-IS* curve utilizes this constraint, however the unconstraint version could be justified along the lines of Davidson et al. (1978) who give a fairly different explanation for the relationship between interest rates and output.

We first estimated the baseline *BL* and *FL* models and found statistically insignificant impact of real interest rate on *GAP1* and *GAP2*. The unconstraint versions also did not produce any significant estimates for the nominal interest and inflation rate elasticities. Extending the *FL* model produced estimates very similar to the baseline models, therefore in the second stage we provide an extension into the *BL* model by including additional terms such as oil price, total government expenditure to GDP ratio, real effective exchange rate, US output gap, growth in real base money, growth in real broad money and growth in real share prices. However, only the latter three variables were found to be statistically significant at the conventional levels. The constraint (unconstraint) version with *GAP2* yields plausible estimates for the real interest rate (nominal interest and inflation rates) elasticity.

To assess robustness of the estimates in our extended *BL IS* curve, we have applied the Quandt-Andrews structural breakpoint tests. The results revealed that there exists a dominant structural break at 1990Q2 and 1996Q1. Both the break dates are expected and highlights the recession which hit the Australian economy in the 1990-91 period and formal endorsement of the inflation targeting regime in 1996. Consequently, considering these break dates we developed sub-samples to investigate if the extended *IS* curve is affected due to these structural changes. In addition, we develop a sample which excludes the global financial crisis period 2007-2010. In all cases, we found the results are consistent with our original extended *IS* curve results.

Finally, our findings can be reliably used by policy makers. The baseline estimates of the *BL* and *FL* model imply that monetary policy is ineffective in steering aggregate demand. However, when the *BL IS* curve is extended with other variables such as the growth in real base money, real broad money and real share prices, we found that the real interest rate (nominal interest and inflation rates) in the constraint (unconstraint) equations are statistically significant at the conventional levels. To this end, monetary policy has significant real effects in the economy. Moreover, our findings suggest that inflation targeting regime did not contribute to any overwhelming effect on output. The inflation targets are achieved via adjusting the market-based instruments like the short-term interest rates, however this monetary policy process did not create any considerable changes in the aggregate demand. Our results also imply that it is vital to integrate other variables (for example, growth in real base money, real broad money and real share prices) in the baseline DSGE models used for monetary policy analysis.

Data Appendix

Table A1. Definitions and Data Source: 1984Q1 – 2010Q3

Variable	Definition	Source
π	Annualized rate of change of GDP deflator: $\left(\ln p_t - \ln p_{t-1}\right) \times 400$	Reserve Bank of Australia (RBA)
y	Output gap obtained with two techniques. *GAP1* is generated by univariate trend-cycle decomposition according to Harvey (1989, 2011). *GAP2* is generated by a quadratic trend (see Ross and Ubide, 2001).	RBA and authors' computations.
i	Quarterly average of the monthly cash rate.	RBA
$Oil_{price}, g, rex, y^{US}$ $\Delta m, \Delta m^b$ and sp	Oil_{price} = cyclical component of natural log of oil price (West Texas Intermediate (US$/BBL)) obtained by univariate trend-cycle decomposition. g = ratio of national real general government final consumption expenditure to real GDP. rex = real effective exchange rate. y^{US} = US output gap (constructed same as y) Δm = year-over-year % change in real base money. Δm^b = year-over-year % change in real broad money. Δsp = year-over-year % change in real share price. Monetary base (broad and narrow) and share prices are deflated by GDP deflator.	RBA, Federal Reserve Economic Database (FED), and authors' computations.

References

Andrews, D. W. K. (1993) Tests for parameter instability and structural change with unknown change point, *Econometrica*, 61, 821-856.

Angeloni, I. and Ehrmann, M. (2007) Euro area inflation differentials, *The B.E. Journal of Macroeconomics*, 7, 1.

Ball, L. (1998) Policy rules for open economies, *NBER Working Paper* No. 6760.

Davidson, J., Hendry, D., Srba, F. and Yeo, S. (1978) Econometric modeling of the aggregate time-series relationship between consumers' expenditure and income in the United Kingdom, *The Economic Journal*, 88, 661-692.

di Giovanni, J., McCrary, J. and von Watcher, T. (2009) Following Germany's lead: using international monetary linkages to estimate the effect of monetary policy on the economy, *The Review of Economic and Statistics*, 91, 315-331.

Estrella, A. and Fuhrer, J. C. (2002) Dynamic inconsistencies: counterfactual implications of a class of rational expectations models, *The American Economic Review*, 92, 1013-1028.

Fuhrer, J. C. (2000) Habit formation in consumption and its implications for monetary policy models, *The American Economic Review*, 90, 367-390.

Fuhrer, J. C. and Rudebusch, G. (2004) Estimating the Euler equation for output, *Journal of Monetary Economics*, 51, 1133-1153.

Goodhart, C. and Hofmann, B. (2005) The IS curve and the transmission of monetary policy: Is there a puzzle? *Applied Economics*, 37, 29-36.

Hafer, R.W., Haslag, J. and Jones, G. (2007) On money and output: is money redundant, *Journal of Monetary Economics*, 54, 945-954.

Hafer, R.W. and Jones, G. (2008) Dynamic IS curves with and without money: an international comparison, *Journal of International Money and Finance*, 27, 609-616.

Hansen, L. (1982). Large sample properties of generalized method of moments estimators, *Econometrica,* 50, 1029-54.

Harvey, A. C. (1989) *Forecasting, Structural Time Series Models and the Kalman Filter*, Cambridge University Press, Cambridge.

Harvey, A. C. (2011) Modelling the Phillips curve with unobserved components, *Applied Financial Economics*, 21, 7-17.

Lindé, J. (2001) The empirical relevance of simple forward- and backward-looking models: A view from a dynamic general equilibrium model, *Sveriges Riksbank Working Paper* No. 130.

Nelson, E. (2001) What does the UKs monetary policy and inflation experience tell us about the transmission mechanism? *CEPR Working Paper* No. 3047.

Nelson, E. (2002) Direct effects of base monetary on aggregate demand: theory and evidence, *Journal of Monetary Economics*, 49, 687-708.

Peersman, G. and Smets, F. (1999) The Taylor rule: a useful monetary policy benchmark for the euro area? *International Finance*, 1, 85-116.

Quandt, R. E. (1960) Tests of the hypothesis that a linear regression system obeys two separate regimes, *Journal of the American Statistical Association,* 55, 324-330.

Ross, K. and Ubide, A. (2001) Mind the gap: what is the best measure of slack in the Euro Area? *IMF Working Paper* No. 203.

Rudebusch, G. (2002) Assessing nominal income rules for monetary policy with model and data uncertainty, *The Economic Journal*, 112, 401-432.

Rudebusch, G. and Svensson, L. (1999) Policy rules for inflation targeting, in *Monetary Policy Rules* (ed.) J. Taylor, University of Chicago Press for NBER.

Stock, J. H. and Watson, M. W. (2001) Vector Autoregressions, *Journal of Economic Perspectives*, 15, 101-115.

Stracca, L. (2010) Is the New Keynesian IS curve structural? *European Central Bank Working Paper Series* No. 1236.

Svensson, L. E. O. (2000) Open-economy inflation targeting, *Journal of International Economics*, 50, 155-183.

Watson, M. (1994) Vector Autoregression and Cointegration, in R.F. Engle and D. L. McFadded (Eds.), *The Handbook of Econometrics*, vol. 4, New York, Elsevier.